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# Development of an Automated Impact Hammer for Modal Analysis of Structures

***P. E. Norman, G. Jung, C. Ratcliffe, R. Crane and C. Davis***

**Air Vehicles Division**

**Defence Science and Technology Organisation**

**DSTO–TN–1062**

## ABSTRACT

This report outlines the development and testing of a prototype compact automated impact hammer designed to be surface mounted on a structure to provide an impulse-based structural excitation source for vibration testing. The automated device was designed to be integrated with a distributed fibre optic sensing system which measures the in-plane dynamic strain of the structure at a spatially dense grid of sensing points. The hammer was tested on a composite plate with induced damage and the excitation and response data were used to generate complex curvature shapes for the plate. These data were in turn used with a structural health monitoring tool known as iSIDER that detects anomalies in complex operating curvature shapes to locate damage and other areas with structural stiffness variations. The impactor was shown to replicate the functionality of a modally tuned impact hammer that had been used previously. The analysed data correctly identified the impact damage location using a fully automated routine.

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# Development of an Automated Impact Hammer for Modal Analysis of Structures

## Executive Summary

This report outlines the development and testing of a prototype compact automated impact hammer designed to be surface mounted on a structure to provide an impulse-based structural excitation source for vibration testing. The automated device was designed to be integrated with a distributed fibre optic sensing system which measures the in-plane dynamic strain response of the structure across a spatially dense grid of sensing points.

The work described in this report forms part of a contribution by DSTO to a research program on Structural Health Monitoring Through Environmental Excitation and Optical Fibre Sensors sponsored by the Office of Naval Research (ONR) under a Naval International Cooperative Opportunities in Science and Technology Program (NICOP). It is a collaborative research effort involving researchers from the US Naval Academy (USNA), Naval Surface Warfare Centre – Carderock Division (NSWCCD), the Australian Co-operative Research Centre for Advanced Composite Structures (CRCACS) and DSTO.

The ultimate goal of the three year research program is the demonstration and validation of a large area vibration-based structural health monitoring system on a large composite sub-structure using simulated environmental excitation and a network of surface-mounted fibre Bragg gratings for response measurement. This report documents an alternative excitation methodology which may be used as part of the structural health monitoring system in the absence of suitable environmental excitation.

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# 1 Background

## 1.1 Experimental modal analysis

Experimental modal analysis involves the study of the dynamic characteristics of a mechanical structure. The goal of modal analysis is to determine the natural frequencies, mode shapes and modal damping of an object or structure, which can be used for a wide variety of applications. The study of changes to or anomalies in the modal characteristics can sometimes be used as a diagnostic tool for health monitoring.

The testing method used to acquire the data for a modal analysis involves the measurement and analysis of the vibrational response at a series of locations on the structure to some applied excitation force. Typically, the response of the structure is measured with accelerometers or a non-contact laser vibrometer and a piezoelectric-based force transducer is used to measure the excitation force. With the input excitation and structural response known, a frequency response function (FRF) between the pairs of excitation and response points can be calculated. An FRF is the transfer function of a linear system and defines the spectrum of the system output relative to the excitation input. Commonly used continuous excitation sources include electrodynamic shakers and servo-hydraulic systems; alternatively, modally tuned hammers provide an impulsive excitation. In the case of broadband noise and swept sine signals, an electrodynamic shaker can be coupled to the structure and used as the excitation source. In the case of impulse excitation, the aim is to have an input with energy at all frequencies in the frequency range of interest. This could be achieved with a perfect impulse with an infinitesimally small duration and infinitely large magnitude. However, an approximation to this can be achieved with a modal impact hammer which imparts a pulse that is approximately a half-sine.

A modal impact hammer is an impactor designed to impart a pulse with a very short duration in order to achieve approximately constant excitation energy in the frequency range of interest. A load cell is incorporated behind the tip of the hammer in order to record the waveform of the exciting force, which is necessary to calculate the FRF.

## 1.2 SIDER

SIDER (Structural Irregularity and Damage Evaluation Routine) is a broadband vibration-based method for locating areas of structural stiffness variation and/or potential damage by looking at features in the complex Operating Curvature Shapes (OCS) of vibrating structures. SIDER was developed by researchers at the US Naval Surface Warfare Center – Carderock Division (NSWCCD) and the US Naval Academy (USNA) for the inspection of large-scale composite structures which are difficult and time consuming to inspect using conventional inspection methods [1].

In order to identify areas of structural stiffness variations with SIDER, a set of experimental OCS must be determined for the structure under inspection. These OCS can be obtained from a set of FRFs measured with a digital spectrum analyser for a grid of test points on the structure. The original SIDER process involved a "roving hammer" approach where an impact excitation is applied with an instrumented hammer across a dense grid of excitation points while the structural response is measured by accelerometers at small number of fixed locations. This method allows for the OCS to be mapped with a spatially dense resolution without the requirement for a large number of sensors and the associated cabling and instrumentation hardware. The drawback with this arrangement is that multiple-point excitation is not feasible for in-service structural monitoring.

It is therefore desirable to modify the SIDER methodology to a “roving response” approach such that a dense measurement grid is used with only a few excitation points, or ideally environmental excitation. The number of sensors required to achieve this renders the use of accelerometers impractical, so the measurement grid is achieved via the use of distributed Fibre Bragg Gratings (FBGs) in optical fibres. The modified approach to SIDER has been given the name iSIDER or inverse SIDER to reflect the fact that the procedure acquires data in an inverse way, such that excitation of the structure occurs at a fixed reference location, where the response is measured at many locations using a large array of surface mounted FBG strain sensors [2].

FBGs are ideally suited to the roving response approach as multiple gratings can be written onto the same optical fibre which allows distributed strain sensing of large structures using a minimal number of optical fibres. Additionally, FBGs are immune to electromagnetic interference, are inherently corrosion-resistant and their size and weight allow them to be incorporated into or onto composite structures with minimal intrusion.

# 2 Introduction

The idea of an automated hammer was conceived to meet several objectives: (i) to replicate the excitation characteristics of a manual hammer; (ii) to reduce the manual effort associated with the repetitive approach; and (iii) by eliminating the variability inherent in manually applied hammer excitation, to improve the data quality for iSIDER tests when using single-point excitation with a distributed Fibre Bragg Grating (FBG) interrogation system for multiple point response measurement.

Commercially available FBG interrogation systems do not have sufficient frequency bandwidth or strain resolution to acquire structural vibration data of satisfactory fidelity for this project. Therefore, an in-house system [3] was developed by researchers at DSTO to overcome these problems. However, one drawback of the system was that only one grating could be interrogated at a time, rather than the preferred simultaneous interrogation of all the gratings. Consequently the reference excitation point had to be impacted separately for each of the FBGs in the grid. This requirement had the potential to introduce variability in the procedure since it is difficult to reproduce precisely the dynamic force and location of a manual hammer impact. It was therefore desirable to produce an automated method of exciting a structure that could provide repeatable impacts that coupled energy into the structure across the required frequency range, and which would also apply the impacts at precisely the same location. In addition, the device was required to integrate with the existing FBG interrogation system so that the excitation triggering and response measurement could be fully automated.

# 3 Development

The four main elements considered in the design of the automated impact hammer were: an actuator to generate the force for the impact; an impact tip; a control circuit to drive the actuator; and a housing to protect and support the various components above the structure under test. The details relating to each element of the design are outlined in the proceeding sections.

## 3.1 Impact tip

As already mentioned, the purpose of the automated impactor was to replace the manual instrumented hammer previously used for iSIDER testing. As such, it was desirable that the impact generated by the automated hammer be as similar as possible to that of the manual hammer, both in magnitude and waveform. The manual hammer previously used had a set of removable screw-in impact tips, however they were not compatible with the load cells available for use with the automated hammer. Therefore some new impact tips and housings (*Figure 1*) were designed. The impact tip housing was machined in aluminium with a screw-thread that could be assembled into the existing load-cells and with a recessed area to hold the impact tip with an interference fit. Tips were machined in both Teflon and Nylon with a similar shape to the manual hammer tip. Teflon and Nylon were chosen because of their availability and because they have similar stiffness characteristics to the tips provided with the manual modal hammer.

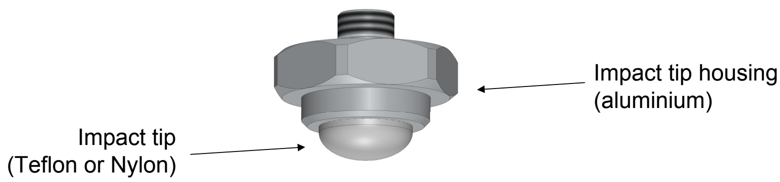


***Figure 1:*** *Impact housing and tip*

## 3.2 Actuator

The aim of the actuator in this design was to accelerate the tip such that it impacts the structure with a repeatable force that can be varied as needed. It was determined that a DC solenoid would provide an effective means to generate repeatable impacts with variable force control. When the solenoid is energised it creates an electromagnetic field that causes the ferrous core mass to accelerate. The kinetic energy of the core at the moment just before the tip impacts the structure will determine the force level generated. When the solenoid is energised by a constant voltage supply, the maximum speed (impact force) is achieved if the solenoid remains energised, and thus keeps accelerating, right up until the tip reaches the surface. The acceleration of the core mass is related to the force exerted on it. The force is, in turn, determined by the voltage with which the solenoid is energised, thus a higher voltage increases the maximum force achievable. Consequently, the force of an impact is directly determined by the excitation voltage and duration of solenoid excitation (or solenoid excitation pulse-width). Some variability in the applied force due to friction in the system is to be expected, however testing showed that the impact force was more repeatable than that obtained with the manual hammer excitation. Hence the solenoid is capable of giving a reasonably repeatable impact (*Figure 2*) with the force adjustable by varying the excitation voltage and pulse-width. Power for the solenoid can be supplied either from mains or with a portable battery pack and preliminary testing with a 12 volts (continuous) rated solenoid indicated that appropriate impacts could be generated with a power supply in the range of 12–35 volts.

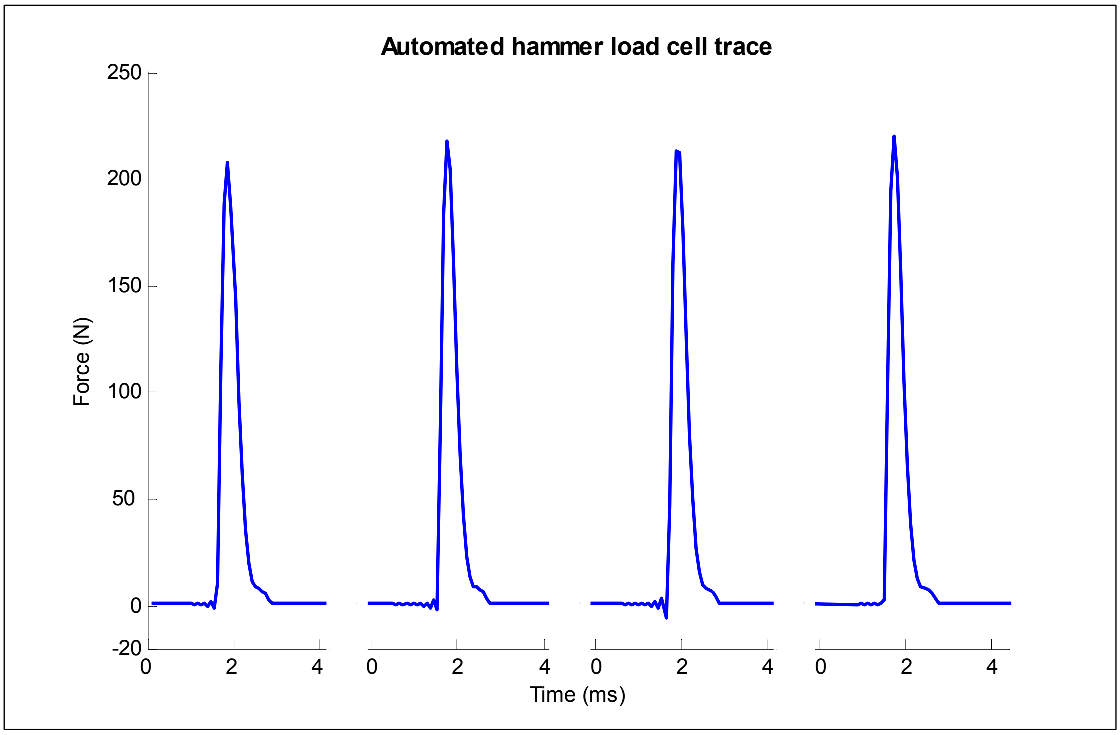


***Figure 2:*** *Impact repeatability – trace recorded from load cell*

One challenge in adapting a solenoid for actuation was finding a way to interface the moving core with a load cell and impact tip. Push-type solenoids of the desired size generally only had a narrow tip protruding from the base. To attach a load-cell would require significant modification so it was decided that a pull-type solenoid would be a better solution. In this type of solenoid, the base could be easily drilled out and an extension piece inserted into to the solenoid core. Using this configuration it was also possible to insert a spring inside the solenoid encircling the extension piece to facilitate return of the core to its starting point after an impact. The extension piece was designed such that a load-cell could be screwed onto the end, which protruded beneath the solenoid as shown in *Figure 3*.

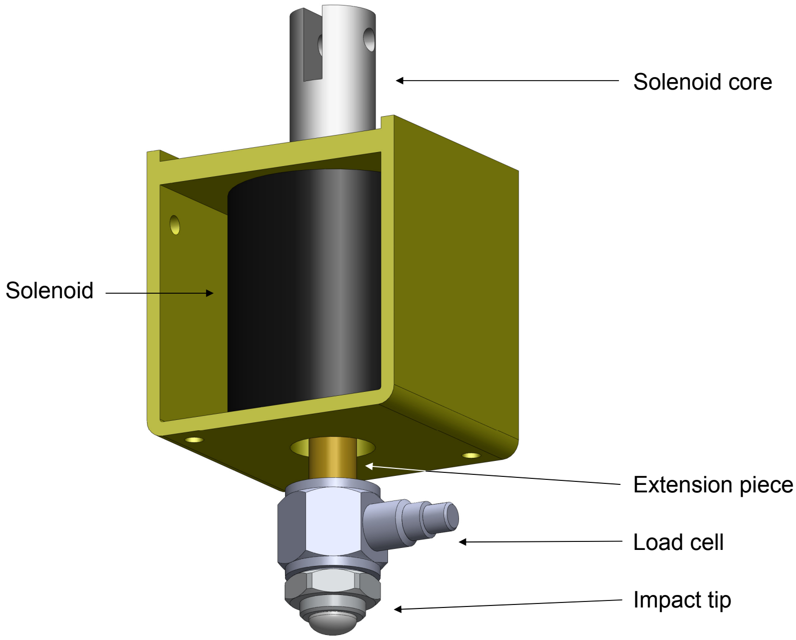


***Figure 3:*** *Solenoid assembly*

## 3.3 Control circuit

To generate an impact the solenoid needs to be driven by an excitation voltage with a short period to accelerate the core and tip toward the structure. Testing was conducted to determine a suitable pulse duration and amplitude to deliver a single impact comparable to that of the manual hammer. The outcome of this testing indicated that the ideal voltage level ranged from 15 to 35 volts and the ideal pulse length was dependent on the distance between the impactor tip and the surface of the structure under test. It was found that in order to deliver a strong enough impact to induce a reasonable structural response without a double-hit that the pulse should end just before the tip of the impactor makes contact with the surface. The pulse length, typically in the range of tens of milliseconds, could be determined for each individual set-up by observing the synchronous time traces of the driving pulse next to the response from the impactor load-cell. The pulse length was adjusted such that the trailing edge occurred just before the load cell indicated contact of the tip (*Appendix A.2*).

A small electric circuit designed to drive the solenoid was fixed inside the impactor housing. The intention was that the circuit would deliver a pulse of variable pre-set length when an external trigger pulse was delivered from a computer parallel port (or other TTL-level device). Initially, an analogue pulse-generation circuit was prototyped using a one-shot monostable multivibrator. The pulse length could be adjusted with a potentiometer and the resulting pulse would switch a transistor delivering high voltage (∼35 volts) to the solenoid. This set-up was tested successfully with the FBG interrogation system.

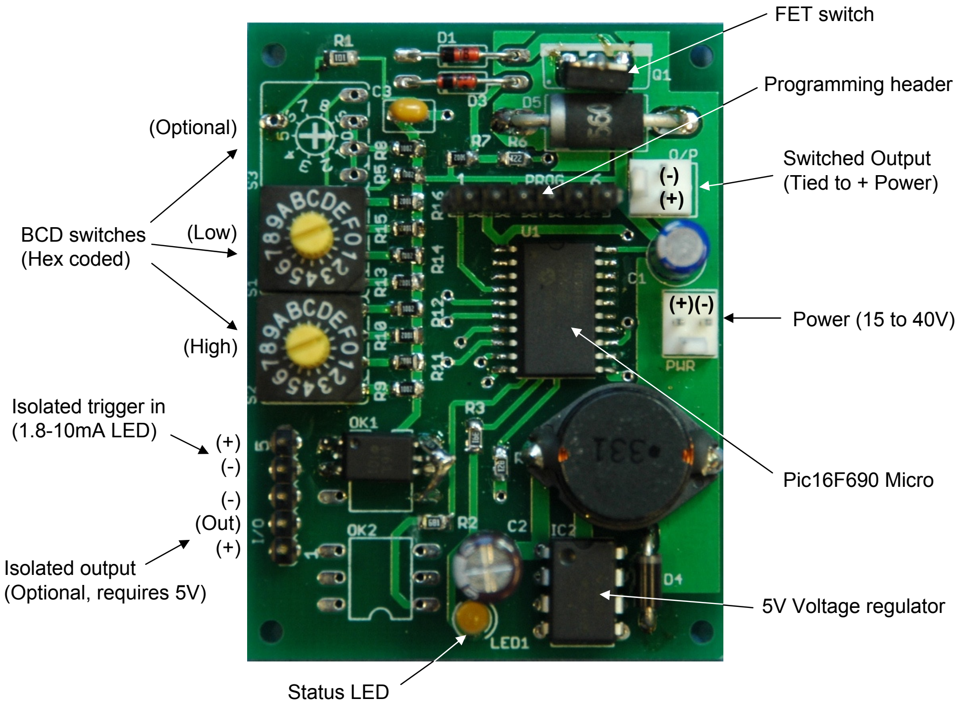


***Figure 4:*** *Impactor control circuit*

During the electronic integration process, the drive circuit was re-designed (*Figure 4*) to incorporate a digitally controlled pulse generator which provided greater controllability of the pulse adjustment. An opto-isolated trigger input to a PIC16F690 microcontroller generates a pulse of 0.5 – 128 ms duration which can be set with a pair of 4-bit rotary switches. The pulse generated by the microcontroller activates a FET switch to deliver power to the solenoid. The redesigned drive circuit requires only a single power supply of between 9 and 50 volts to drive the solenoid and it can be triggered using an ordinary PC parallel port or other similar TTL-level source.

## 3.4 Housing

The housing of the automated impact hammer is designed to contain the actuator and all of the necessary drive circuitry. The only connectors exterior to the housing are for the power supply, the trigger signal and transmitting the force data (from the load cell). The digital switches for adjusting the pulse duration are accessible from the exterior of the structure via a pair of small holes into which a small screwdriver can be inserted.

The housing allows for the height of the impactor above the structure to be adjusted. This enables compensation for variability in the system which may arise from the use of different springs, impact tips or load cells. Four levelling feet support the housing and can be individually adjusted to accommodate surfaces that are not completely flat (see *Figure 5*).

Another design consideration for the housing was the weight of the entire assembly. The heavier the assembly, the more likely it is to change the dynamic characteristics of the structure under test. At the same time, if the housing is too light the reaction force from the solenoid will cause it to recoil from the surface. An early prototype housing design showed significant recoil from the structure at the force levels required. The final housing was constructed to be heavier (from 6 mm thick aluminium), to reduce the chance of recoil. Typically, the iSIDER results adjacent to the excitation location are excluded from the analysis. However, further testing remains to be completed on the mass-loading effects of this device for modal testing on different structures.

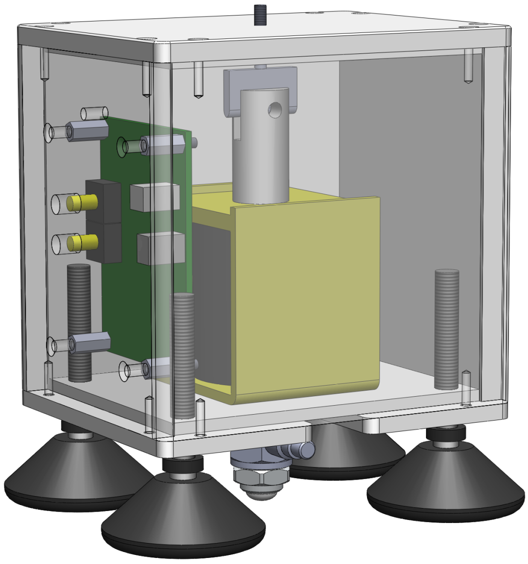

***Figure 5:*** *Housing design showing solenoid actuator and control circuit PCB*

## 3.5 Integration with FBG interrogation system

The automated impact hammer was designed to be integrated into a previously developed FBG interrogation system described in [3]. The system uses a tuneable laser source to select individual gratings and a photodiode connected to a frequency analyser to measure the dynamic response. The system had previously been configured to interrogate gratings with sustained excitation by a shaker, or impulse excitation by an instrumented hammer. The system set-up for impulse excitation required human involvement during a test both to operate the hammer and to save the individual data sets using the frequency analyser. The new device removes the requirement for manual operation of the hammer, but for fully autonomous operation the data acquisition also required automation. The data could not be saved automatically by the frequency analyser when operated in real-time analysis mode. However, autonomous acquisition could be achieved by configuring the analyser as a waveform recorder which could be instructed to begin recording by the FBG switching system. This was done previously when shaker excitation was used, and the frequency analysis could be performed by processing data after completion of the test. As operating the system with automated hammer excitation would be similar to operating with shaker excitation, the shaker excitation configuration was used with some modifications to accommodate a trigger signal for the hammer (see *Figure 6*).

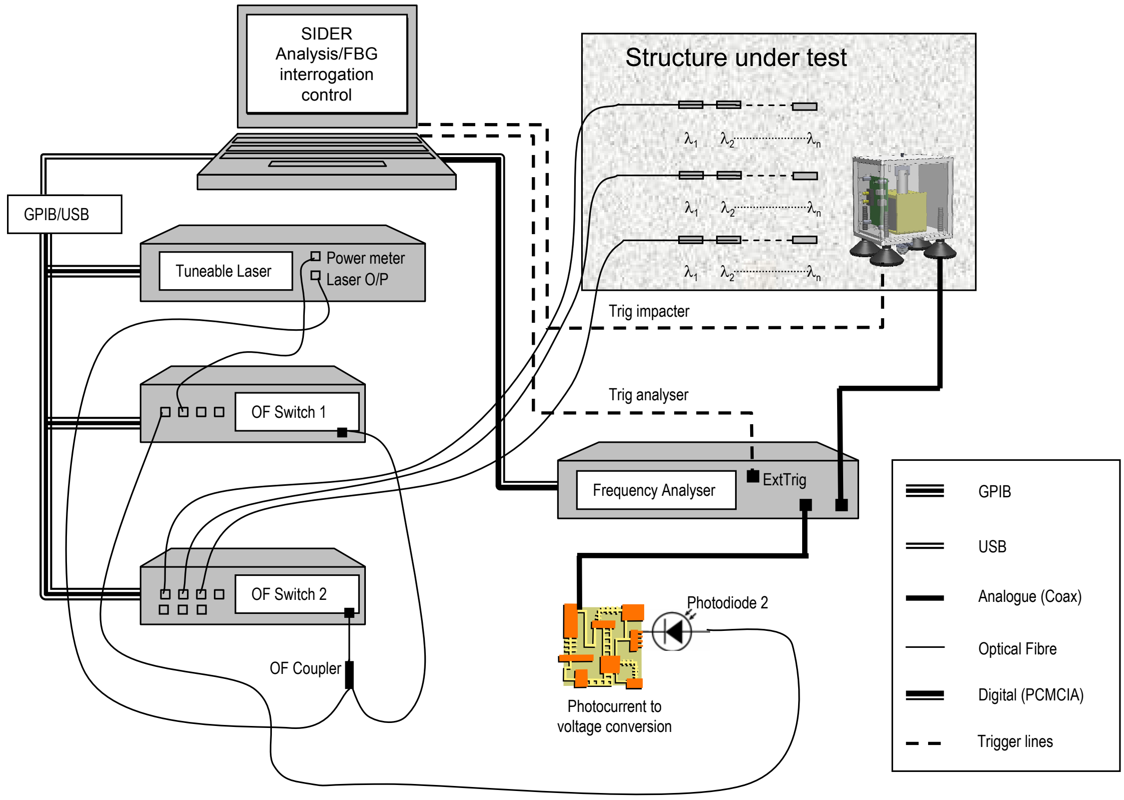


***Figure 6:*** *Diagram showing modified interrogation set-up to incorporate automated impactor and response measurement*

In the previous configuration, a single trigger signal had already been implemented to instruct the frequency analyser to begin recording once the tuneable laser had selected a sensor. In order to integrate the automated impactor, a second trigger channel was added and set-up to send a number of pulses, with a pre-set delay between each, after the frequency analyser was instructed to start. With this second trigger channel connected to the trigger input of the automated impactor, the system can coordinate a series of impacts after the frequency analyser begins recording for each grating. A schematic timing diagram is shown in *Figure 7* to illustrate the modified external trigger implementation where the auto-impactor is configured to impact twice for each grating. The number of impacts for each grating is user configurable depending on the application.

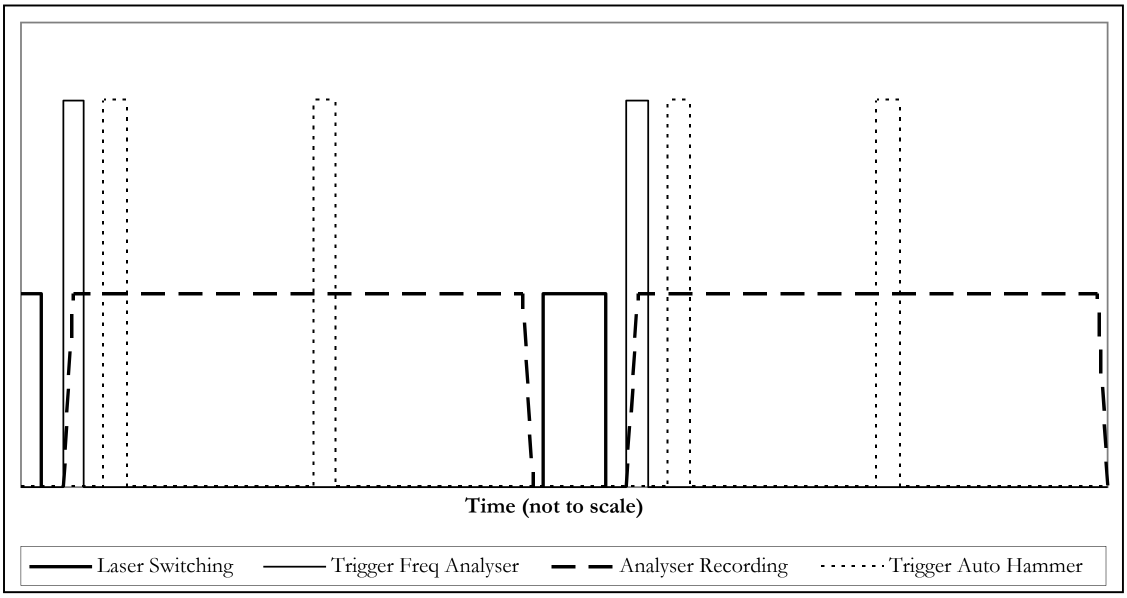


***Figure 7:*** *Illustration of modified external trigger implementation*

# 4 Experimental validation

The iSIDER routine was used to inspect a glass fibre test panel with a quasi-isotropic lay-up in E-glass/vinyl ester (1.32 m [52”] long, 0.81 m [32”] wide, & 6 mm [1/4”] thick). Prior to the inspection the test panel was damaged in two areas with different impact energy levels, 68 J (48.8 ft-lb) and 108 J (76.3 ft-lb). A set of 10 optical fibres each containing 10 FBG sensors spaced at 50.8 mm (2 inch) intervals was adhered to the surface of the plate using Kapton® self-adhesive pressure-sensitive tape. The panel was laid horizontal on two layers of bubble wrap supported on a large table as shown in *Figure 8*. The initial iSIDER inspection used a manual instrumented hammer to excite the structure and the response was measured for each of the FBGs. FRFs were obtained then analysed using the iSIDER algorithm, which first generates frequency dependent OCS from the FRFs and then looks for anomalies in the OCS. These anomalies are represented by an irregularity index which is presented graphically as a contour plot overlaid on a diagram of the structure. Both the heavy and light damage areas could be located using the manual hammer method as indicated by the contour map shown in *Figure 9*.

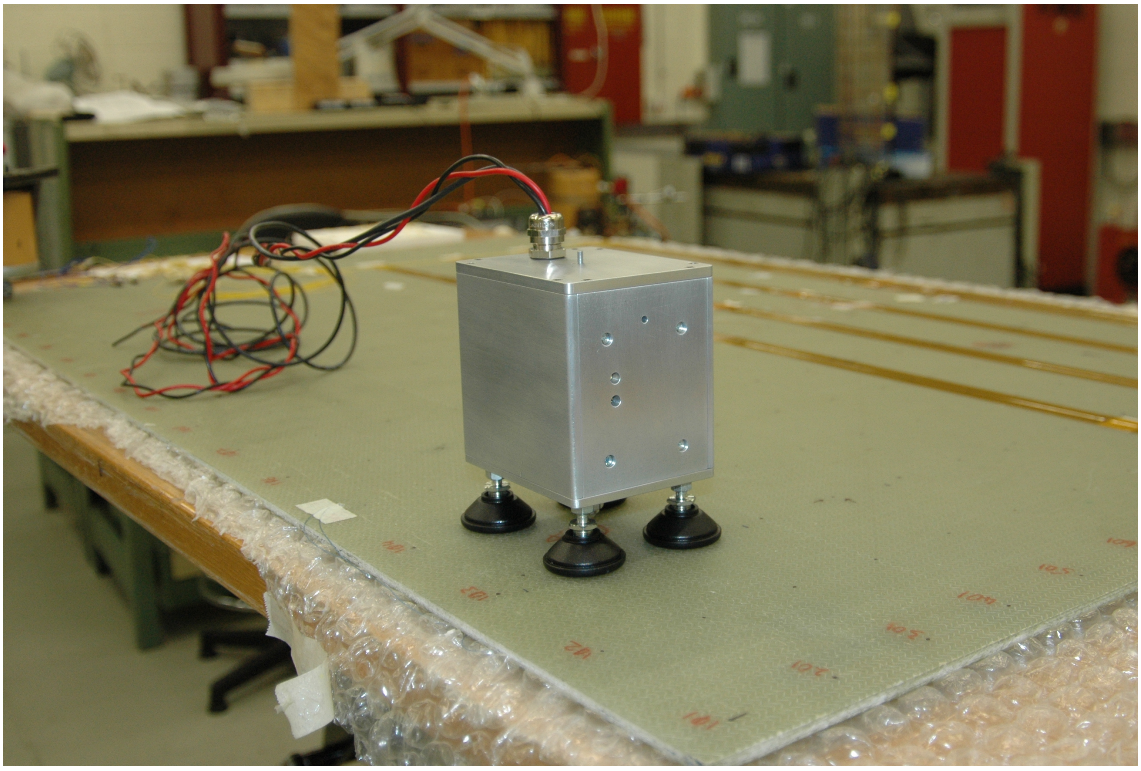

***Figure 8:*** *Impactor on a composite plate supported by bubble wrap*

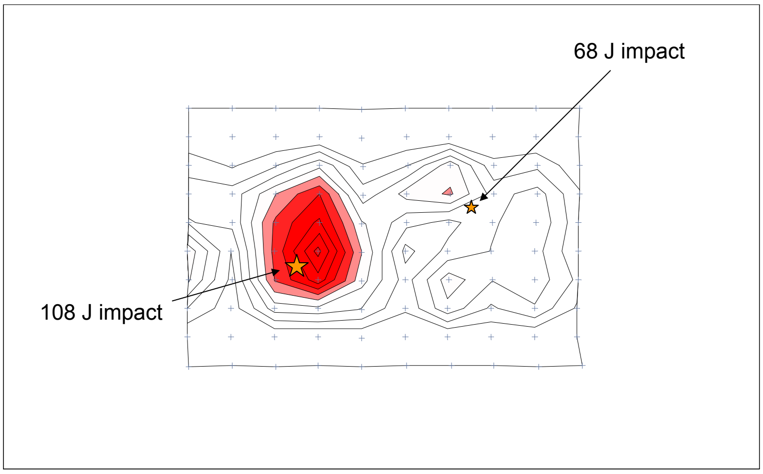


***Figure 9:*** *iSIDER analysis of manual hammer data*

Experimental validation of the automated impact hammer was performed by using the same test article and substituting the manually operated modal hammer with the automated impact hammer and the FBG interrogation system. For this test, the FBG sensors were positioned to interrogate the plate only in the region containing the heavy impact site. At the time of testing, the housing and integrated drive circuitry had not yet been completed, so a bench-top digital function generator was used to produce a square pulse which controlled a prototype drive circuit, and the impact assembly was mounted on the structure using a temporary housing arrangement. Using the same methodology as for the manual hammer testing, the panel was excited and the response recorded for each FBG sensor. This was done with the automated hammer assembly positioned at each of the four reference points where the manual hammer was used.

As with the manual hammer method, the automated impactor iSIDER results were plotted on a contour map as shown in *Figure 10*.

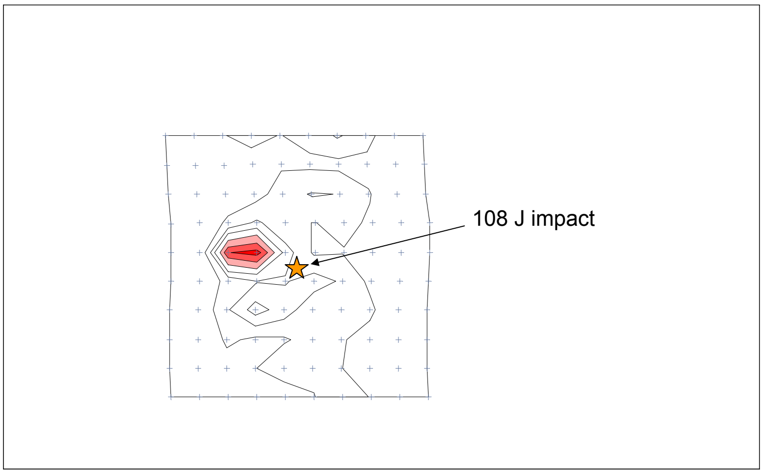


***Figure 10:*** *iSIDER analysis of automated impactor data*

The contour map shows a clearly identifiable feature that is near the heavy damage location on the plate as was seen for the manual hammer excitation on the same plate. This result shows that the automated impactor can be successfully used with iSIDER as an alternative to manual hammer or environmental excitation. Further testing is recommended to compare the relative effectiveness of the different excitation techniques in detecting damage using the iSIDER routine.

# 5 Conclusions

A prototype compact automated impact hammer has been designed for surface mounting on structures to provide an impulse-based structural excitation source for vibration testing. Accompanying hardware and software were developed to facilitate the automation and control of the excitation impulse magnitude and duration and to interface the excitation source with a network of FBG sensors for response measurement of the structure under test. The ability of the automated impactor to replace a manually operated instrumented impact hammer was validated by conducting an iSIDER analysis on an impact damaged composite panel using both excitation methodologies. Both iSIDER analyses, conducted using manual and automated excitation, showed a large feature near the damage location.

The results from preliminary testing of the automated impact hammer are promising and suggest that the device can provide a satisfactory alternative excitation methodology for iSIDER where a suitable environmental excitation is not available. However, it should be noted that the prototype device was designed to impart a relatively low impact energy and is therefore only suitable for application to small structures. A redesign of the actuator, impact tip and housing would be required to induce the energy levels appropriate for large-scale structural excitation.

# 6 Acknowledgements

The authors gratefully acknowledge the Office of Naval Research for the support of this work under the Naval International Cooperative Opportunities in Science and Technology Program (Grant No. N00014-09-1-0364; program sponsor Dr. Ignacio Perez). The authors also thank Chris Rider (DSTO) for advice relating to the impactor tip design and load cell integration and Anthony Rizk for assistance with the experimental validation.

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2. Roger Crane, Colin Ratcliffe, Claire Davis, Patrick Norman, and Anthony Rizk, NSWCCD-65-TR-2011/20, *"Development of the iSIDER Inspection Method Using Bragg Gratings to Identify Impact Damage in Composite Plates"*, (2011).

3. P.E. Norman and C.E. Davis, Technical report DSTO-TR-2370, Defence Science and Technology Organisation (DSTO) Australia, *"An intensity-based demodulation approach for the measurement of strains induced by structural vibrations using Bragg gratings"*, (2009).

# Appendix A Operation

## A.1 Specifications

| | | |
|---|---|---|
| Supply voltage | Recommended | 12 – 40 V |
| | Limits | 9 – 50 V |
| Max. switching current | Pulse (100 ms) | 10 A |
| | Continuous | 3 A |
| Trigger | Min. current | 1.8 mA |
| | Min. duration | 1 ms |
| | Latency | 1 ms |
| Output pulse | Range | 0.5 - 128 ms |
| | Resolution | 0.5 ms |
| Typical operation | Voltage | 35 V |
| | Pulse length | 10-15 ms |

## A.2 Set-up optimisation

To achieve an optimum hit for a given supply voltage the solenoid should remain energised until the moment before the impact tip makes contact with the surface of a structure. The following steps detail the procedure to optimise the drive circuit pulse length to achieve this:

1. Connect the supply voltage line to a power supply.
2. Connect the load-cell to a digital frequency analyser/data acquisition system.
3. Connect the trigger line to a trigger source (control laptop) and using a T/Y-connector, also connect it to a second channel on the frequency analyser/data acquisition system.
4. Configure the data acquisition system to display the traces of both the load-cell output and the trigger-line output (set the acquisition to trigger from a rising edge on the trigger-line).
5. Set the desired supply voltage (15-35 V recommended), and set the pulse length to the shortest possible.
6. Using the control laptop, trigger the impactor. Nothing should happen.
7. Increase the duration one step at a time using the rotary switches accessible from the housing, triggering the impactor after each increase. Observe that the impact tip begins to move. Continue increasing the pulse duration and triggering the impactor

until an impact occurs and the load-cell response appears on the acquisition system display.

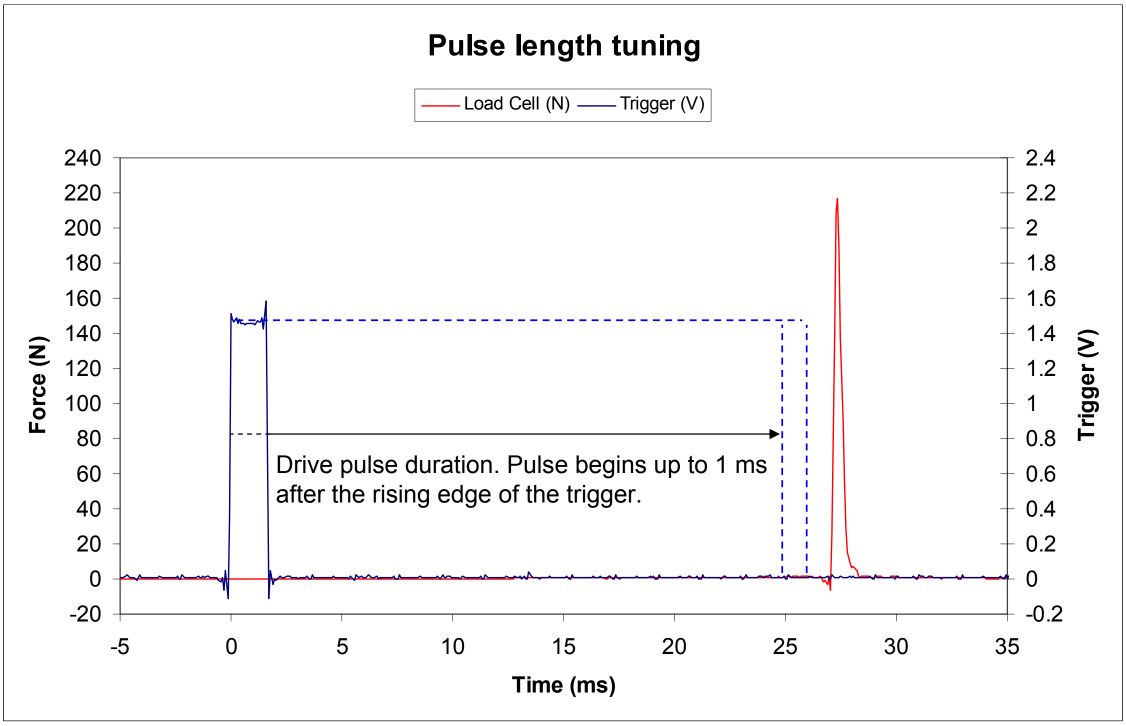


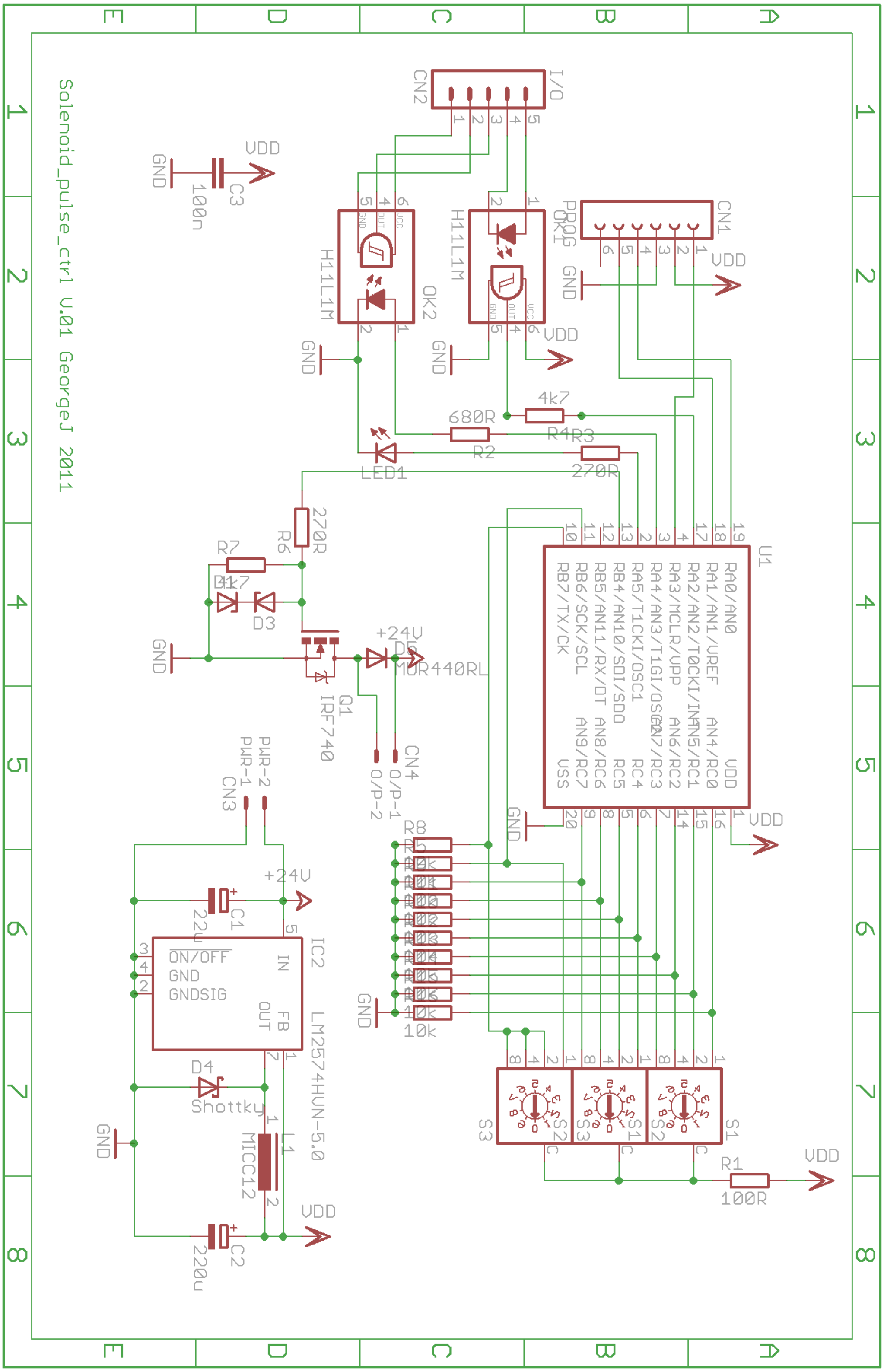

***Figure A1:*** *Tuning the pulse length – the dotted line represents the solenoid drive pulse which initiates during the trigger pulse and terminates after the duration assigned with the digital switches (in this example, 25 ms)*

8. Observe the time between the trigger signal and the load-cell response signal (*Figure A1*). Ideally the length of the pulse should equal the span between the trigger and load-cell signals. However, as the pulse length is increased the tip will accelerate for a longer period so the load-cell will make contact sooner, therefore a shorter pulse length will be required.

9. Incrementally increase the pulse length and observe the converging signals until the duration is set such that the pulse ends slightly more than 1 ms before[1] the load-cell signal records contact. NOTE: The impact force will increase as the pulse duration is made larger. It may be necessary to lower the supply voltage and repeat the process of increasing the pulse length to achieve the desired force level.

[1]This gap is to allow for the variable trigger latency which may be up to 1 ms

# Appendix B Control circuit schematic

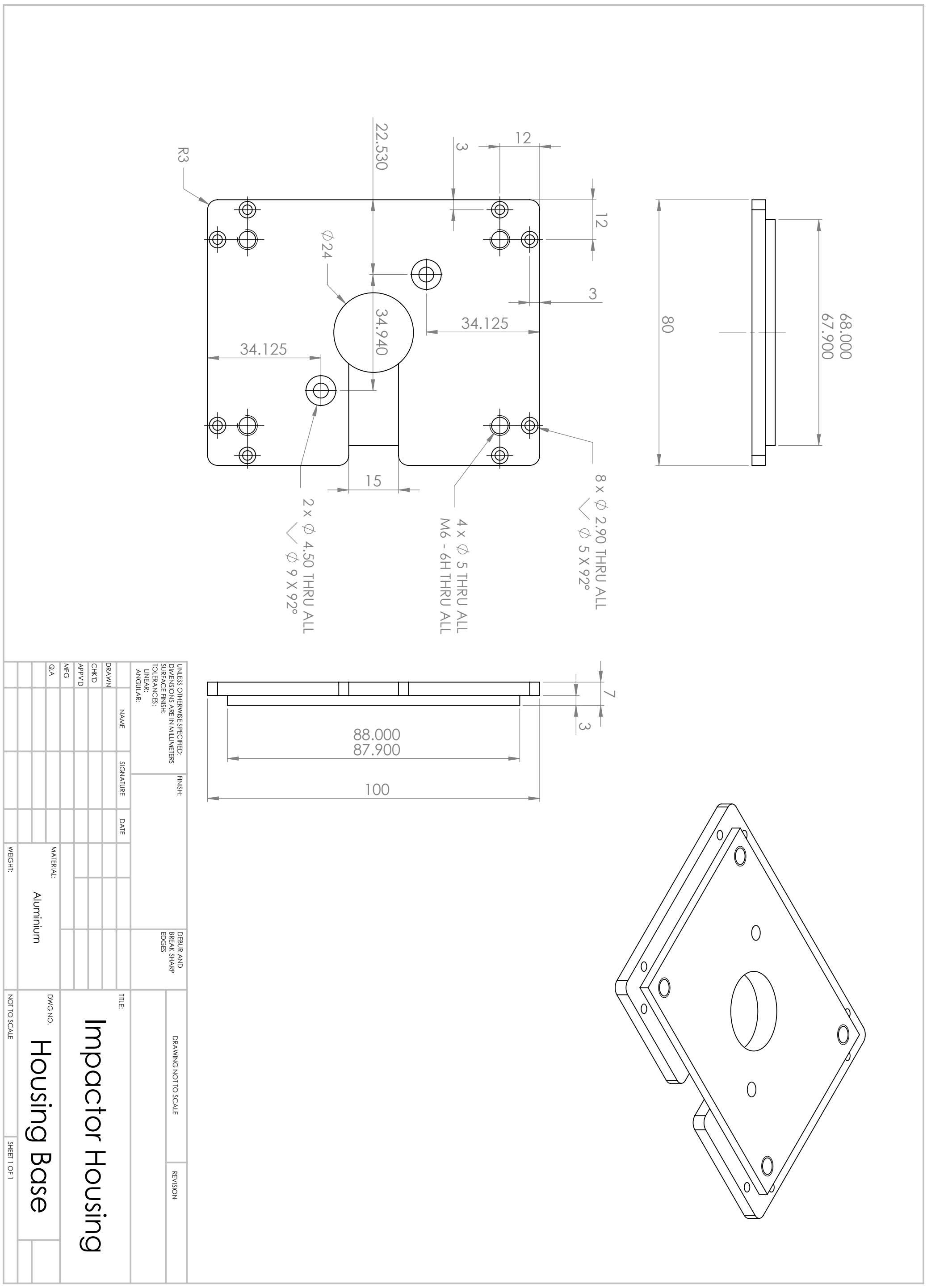


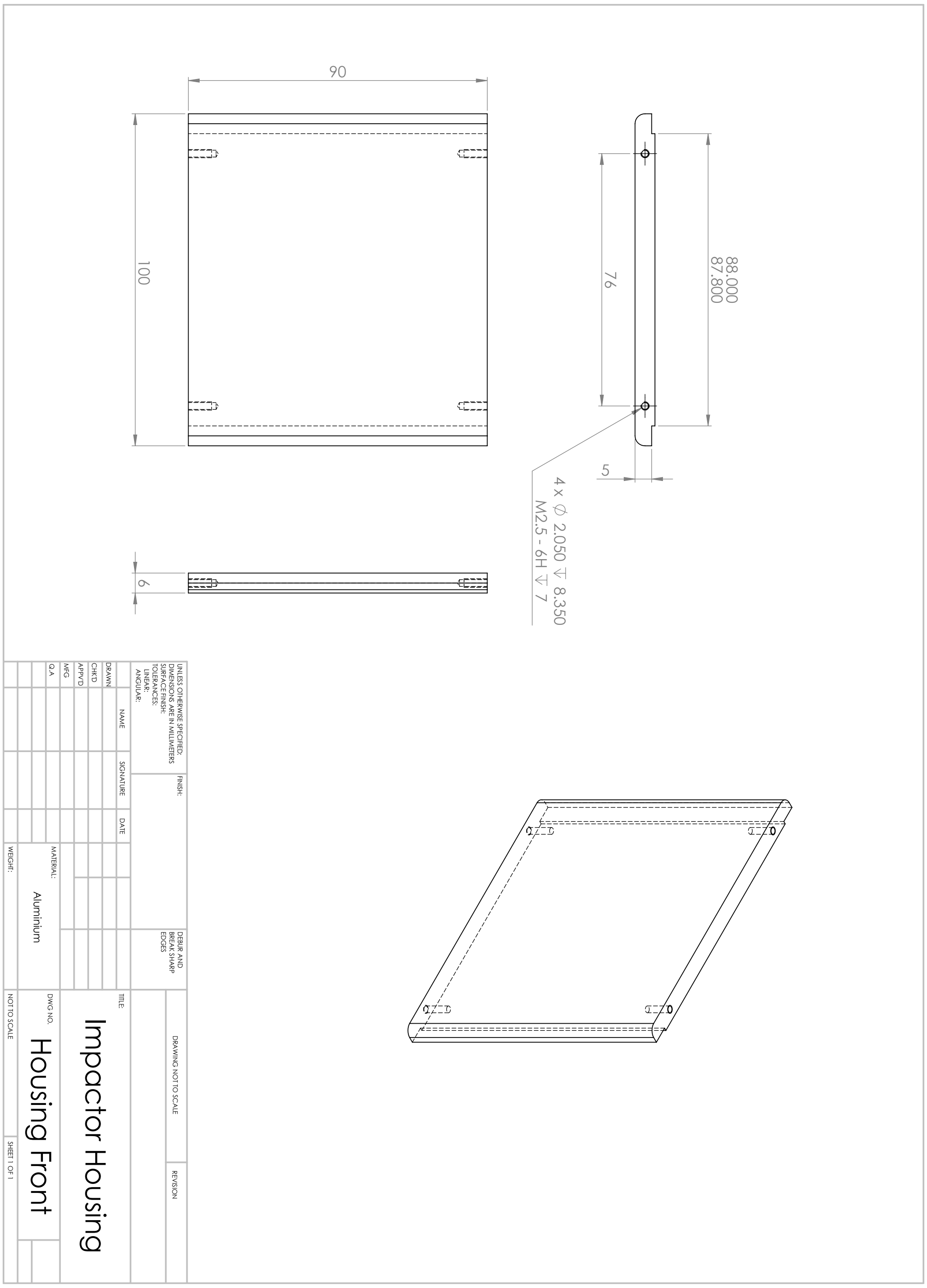
# Appendix C Control circuit code

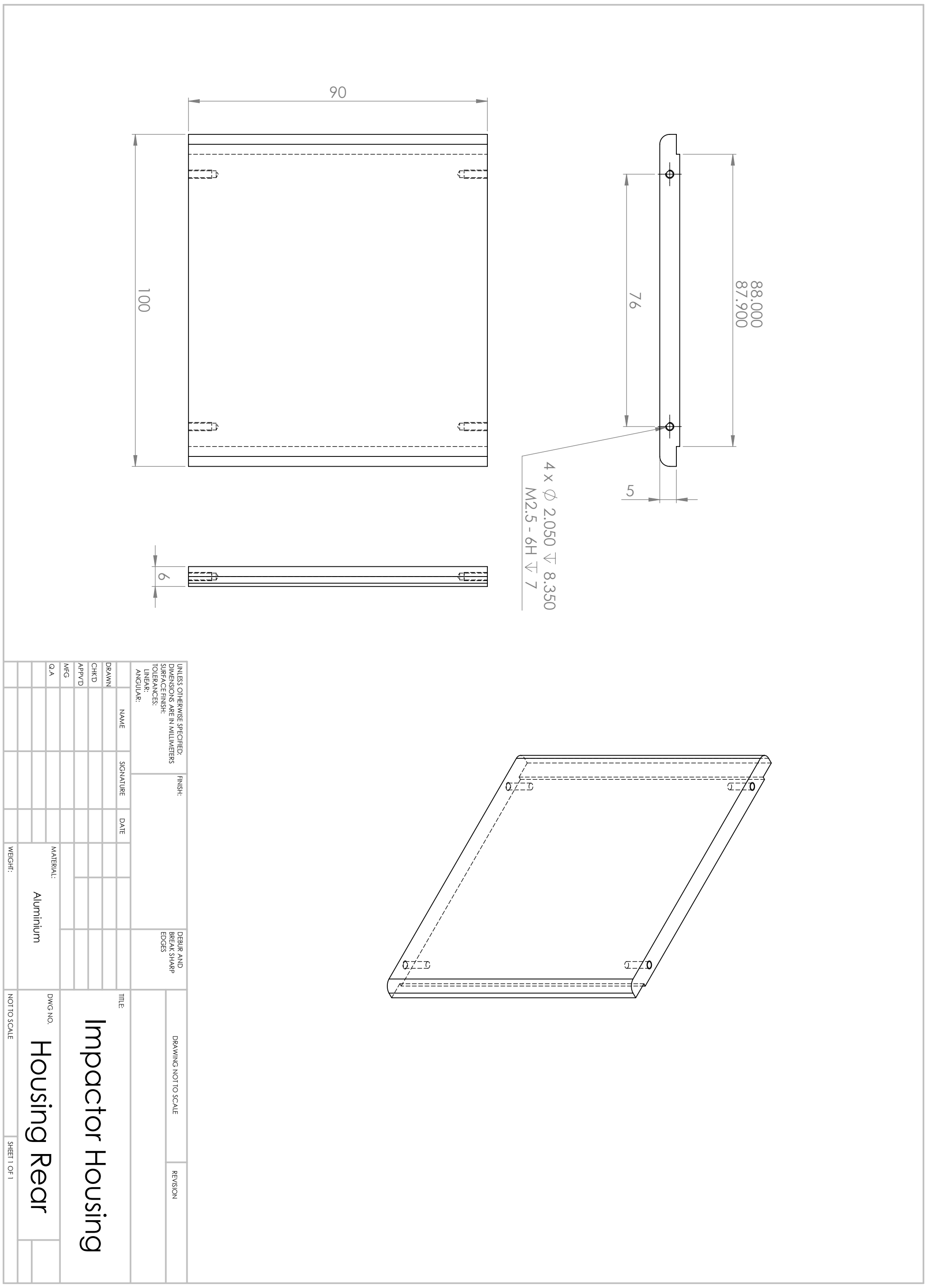
```
'*************************************************************
'*  Name    : Delay_pulse.BAS                                *
'*  Author  : George Jung                                    *
'*  Date    : 19/02/2011                                     *
'*  Version : 1.0                                            *
'*  Notes   : Firmware to control solenoid hammer pulse duration *
'*          :                                                *
'*************************************************************
'
' PIC16F690 Hardware connections
'
' RA0   Prog pin
' RA1   Prog pin
' RA2   Trigger in/INT pin
' RA3   MCLR (Programming pin)
' RA4   Trig out LED
' RA5   Indicator LED
' RC0...7   BCD switches 1,2
' RB4   Output for driver FET
' RB5   NC
' RB6   BCD switch 3
' RB7   BCD switch 3
'
'------------Defines--------------------------

 include "modedefs.bas"
 define OSC 4               ' For pause to have 0.5ms resolution!
 OSCCON = %01110001         ' 8MHz internal oscillator
 OPTION_REG = %10000111
 INTCON = %10010000
 ANSEL = %00000000     ' all ADC's off

 ' -----------Variables----------------------

LED var Porta.5
 TRIG var Porta.4          ' Trigger I/P port
 SW var Portb.4            ' 8-bit BCD switch port
 Delay var word
 tmp2 var word
 tmp3 var word
 tmp var Portc
 N var byte                ' loop variable
```

```
 '--------Initialisation ----------------------

Init:
    trisa = %00001100
    trisb = %00010000
    trisc = %11111111     ' all port C pins are inputs
    low SW
    Delay = 1           ' start with 1ms delay

 on interrupt goto Delaynow
 goto Start
 DISABLE INTERRUPT

 ' -----------ISR should go here ----------------

Delaynow:
 high Trig
 high SW
 high LED
 pause Delay
 low TRIG
 low LED
 low SW
 INTCON = $90          ' reset interrupt flag
 resume

 ' --------------------------- Main code ------------------------

Start:
 tmp2 = 0
 tmp3 = 0
 high LED         ' blink LED

 Delay = tmp
 pause 1
 low LED
 ' ---------------- Only allow interrupts in this code segment! -------
 enable interrupt
 for N = 1 to 200
    pause 1
 next N
 Disable interrupt
 goto Start      ' loop forever

 END
```

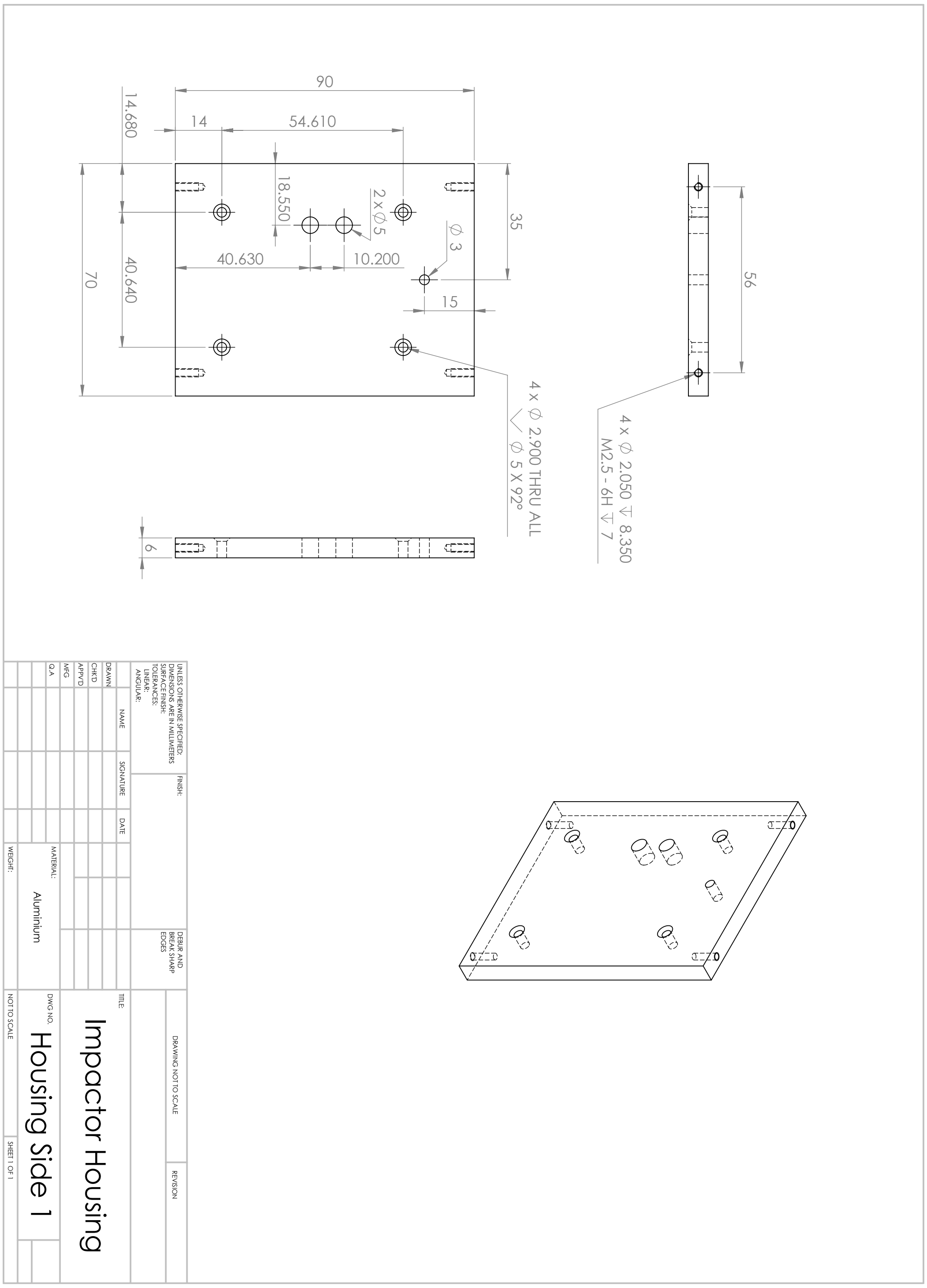
# Appendix D Housing component drawings

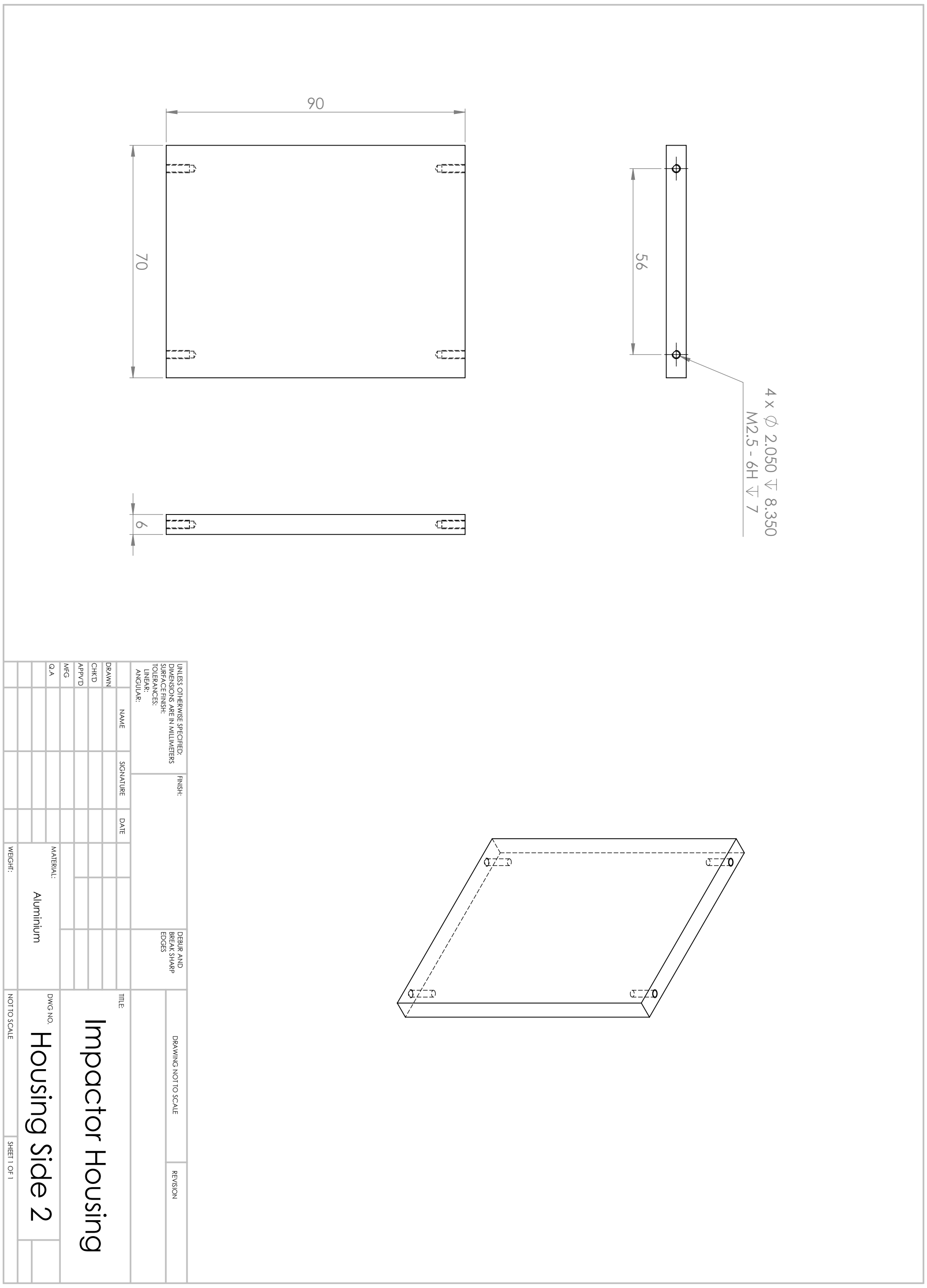


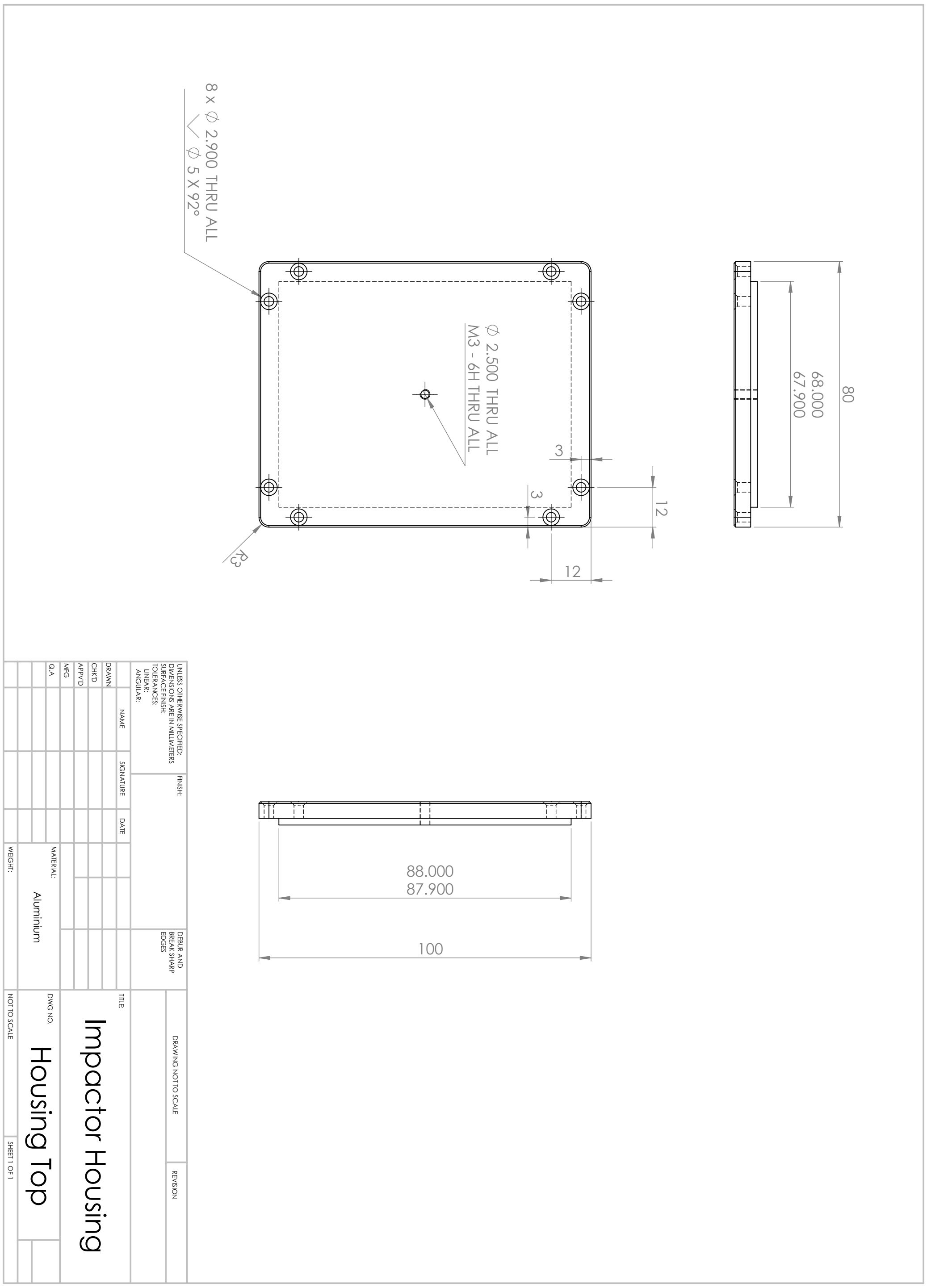

90
100
76
88.000
87.800
5
6
4 x Ø 2.050 ⊽ 8.350
M2.5 - 6H ⊽ 7
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DRAWING NOT TO SCALE
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Impactor Housing
DWG NO.
Housing Front
NOT TO SCALE
SHEET 1 OF 1

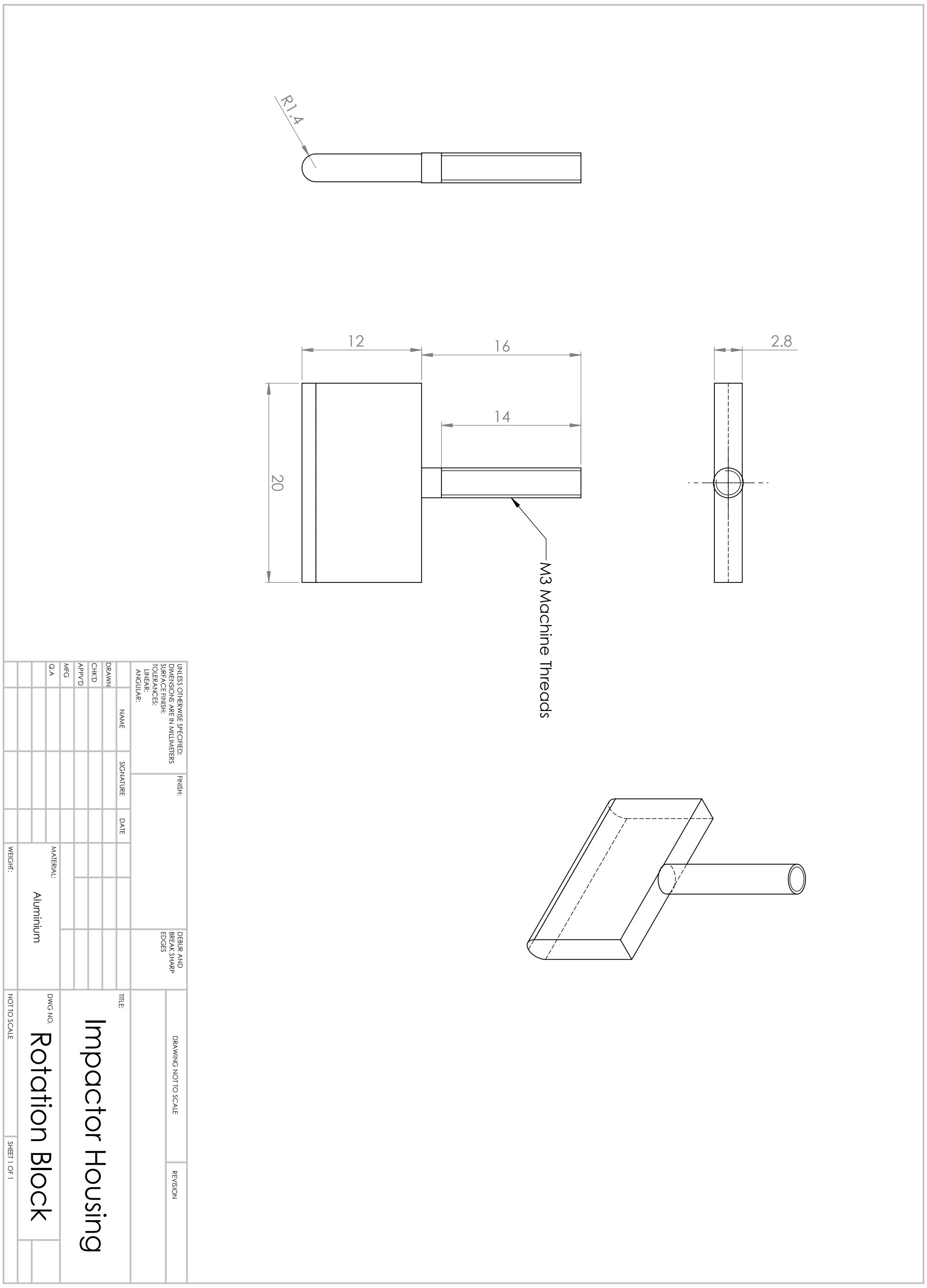


90
100
76
88.000
87.900
5
6
4 x ⌀ 2.050 ↧ 8.350
M2.5 - 6H ↧ 7
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DRAWING NOT TO SCALE
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Impactor Housing
DWG NO.
Housing Rear
NOT TO SCALE
SHEET 1 OF 1


90
14
54.610
14.680
18.550
2 x Ø 5
Ø 3
35
40.630
10.200
15
70
40.640
56
4 x Ø 2.900 THRU ALL
Ø 5 X 92°
4 x Ø 2.050 ▽ 8.350
M2.5 - 6H ▽ 7
6
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DRAWING NOT TO SCALE
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Impactor Housing
DWG NO.
Housing Side 1
NOT TO SCALE
SHEET 1 OF 1


90
70
56
6
4 x ⌀ 2.050 ↧ 8.350
M2.5 - 6H ↧ 7
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DRAWING NOT TO SCALE
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Impactor Housing
DWG NO.
Housing Side 2
NOT TO SCALE
SHEET 1 OF 1


8 x ⌀ 2.900 THRU ALL
⌀ 5 X 92°
⌀ 2.500 THRU ALL
M3 - 6H THRU ALL
3
3
12
12
R3
68.000
67.900
80
88.000
87.900
100
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DRAWING NOT TO SCALE
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Impactor Housing
DWG NO.
Housing Top
NOT TO SCALE
SHEET 1 OF 1


R1.4
12
16
14
20
2.8
M3 Machine Threads
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DRAWING NOT TO SCALE
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Impactor Housing
DWG NO.
Rotation Block
NOT TO SCALE
SHEET 1 OF 1

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19. ABSTRACT

This report outlines the development and testing of a prototype compact automated impact hammer designed to be surface mounted on a structure to provide an impulse-based structural excitation source for vibration testing. The automated device was designed to be integrated with a distributed fibre optic sensing system which measures the in-plane dynamic strain of the structure at a spatially dense grid of sensing points. The hammer was tested on a composite plate with induced damage and the excitation and response data were used to generate complex curvature shapes for the plate. These data were in turn used with a structural health monitoring tool known as iSIDER that detects anomalies in complex operating curvature shapes to locate damage and other areas with structural stiffness variations. The impactor was shown to replicate the functionality of a modally tuned impact hammer that had been used previously. The analysed data correctly identified the impact damage location using a fully automated routine.